Newcastle University e-prints

Date deposited: 19th May 2010

Version of file: Author, final

Peer Review Status: Peer Reviewed

Citation for published item:

Jehanfo S, Dissanayake D. Modelling Surface Access Mode Choice of Air Passengers. *Proceedings of the Institution of Civil Engineers: Transport* 2009,**162** 2 87-95.

Further information on publisher website:

http://www.icevirtuallibrary.com/content/journals

Title: Modelling Surface Access Mode Choice of Air Passengers

Keywords: airport-access, discrete-choice, revealed-preference,

Author Details:

Suweidu Jehanfo, BSc, MSc*
Transport Modeller
Mott MacDonald
Integrated Transport Division
Canterbury House
85 Newhall Street
Birmingham, B3 1LZ
United Kingdom
Tel: +44 (0) 121 237 4229
Fax: +44 (0) 121 237 4003
E-mail: suweidu.jehanfo@mottmac.com

Dilum Dissanayake, BSc, MEng, PhD.
Lecturer in Transport Modelling
Transport Operations Research Group
School of Civil Engineering & Geosciences
Newcastle University
Newcastle, NE1 7RU
United Kingdom
Tel: +44 (0) 191 222 5718
Fax: +44 (0) 191 222 6502
E-mail: dilum.dissanayake@ncl.ac.uk

* Corresponding author

ABSTRACT

Disaggregate Demand Analysis based on Utility Maximisation is carried out in this study using revealed data on air passengers. Models are developed that explain passengers' choice of ground access mode in terms of access-time, household car-ownership, size of the access group and luggage-count. Market segmentation allows sub-models to be developed for leisure passengers, business passengers, passengers on domestic flights, passengers on international flights, passengers who earn less than £20,000 a year and passengers with an annual income of £20,000 or more. A Multinomial Logit approach is adopted considering its suitability in this study where the choice set consists: car (long-stay parking), car (drop-off), taxi, metro and bus. Newcastle International Airport (NCL), located in the northeast of England, is chosen as the case study. The addition of an extra automobile in a passenger's household is found to increase (×6) the odds of using car (long-stay parking) rather than bus. Business travellers are found in this study to be more sensitive to access-time than passengers travelling mainly for leisure. Passengers to domestic destinations tend to be more sensitive to access-time compared to their international-bound counterparts. Passengers who earn £20,000 or more value access-time more than passengers earning less than £20,000.

INTRODUCTION

The dramatic growth in the demand for air travel has been reaffirmed in recent airport studies. Aviation growth has now been forecasted to double in the next 20 years and treble in the next 30 years[1] with consequent growth in the number of surface-access trips made to airports mainly by air-passengers. The issue of airport surface-access has been addressed by airport planning authorities where attempts are made for the airport to be linked to the ground transportation system. With increasing societal concerns about highway congestion and the environmental impacts of highway traffic, many of the world's largest airports are now aiming to improve public modes. Governments have increasingly become involved in the campaign to promote the use of public transport to airports and this has subsequently led to the implementation of major legislation such as Airport Surface Access Strategies (ASAS) in the UK and Intermodal Surface Transportation Efficiency Act (ISTEA) in the US. These two pieces of legislation commonly aim at promoting the use of public transport by linking airports to the existing ground transportation system. In order to gain approval for further expansion of facilities (runways and terminals), airports above a certain size in the UK are now required to come up with a comprehensive and approved ground access strategy.

FIGURE 1 depicts modal share statistics compiled in 2003 by the Civil Aviation Authority (CAA) for major UK airports. The results indicate an overwhelming use of the automobile by air passengers in accessing airports. As such, managers and airport authorities would wish to pursue those improvements that passengers are revealing as most important in their choice of a transport mode to an airport. It is against this background that this work derives its motivation. The principal objective of this study is to analyse the behaviour of air-passengers when confronted with the independent decision of choosing an airport ground access mode.

DISAGGREGATE MODELLING OF AIR TRAVEL DEMAND

Disaggregate modelling continues to increase in popularity mainly because of its firm behavioural emphasis but also largely due to the fact that it is able to address the issue of huge data collection costs associated with previous techniques. Disaggregate modelling avoids aggregating, averaging and the use of "granular" data cited by Cunningham and Gerlach[10] to largely affect the precision of airport ground access models. Based on research results on focus group discussions at 18 leading airports in the US, Cunningham and Gerlach[10] find decision makers commonly referring to "lack of vision" and the "inability to capture broad socioeconomic implications" as the greatest limitations of quantitative modelling in the strategic decision making process.

In one of the earliest studies on disaggregate modelling of airport choice; Skinner[2] uses a Multinomial Logit (MNL) structure for airport choice analysis in the Baltimore-Washington D.C. area. The independent variables used were access costs and frequency of flights. In assessing the utility of passengers, access-time performed just as well as access-cost. Ground costs were relatively more important to non-business travellers than to business travellers in their choice of airports and elasticities associated with ground access were much higher than elasticities associated with flight frequencies.

Pels et al.[3] performed a Nested Logit (NL) analysis of the combined choice of airport and airline. Alternative formulations of the tree structure were developed and it was found that the best explanation of the airport-airline choice occurred with the airport choice at the upper level and the airline choice at the lower level. This formulation proved statistically and theoretically superior to the nested model with a reversed decision tree for both business and leisure travellers in the San Francisco Bay area. It also outperformed the MNL model.

Bhat[4] attempted to address the issue of latent availability as applied to airport choice analysis and acknowledges that not all passengers consider all available airports. In order to do this, Bhat[4] proposed the use of a two-level modelling structure in which airport choice is preceded by a choice generation stage. A Probabilistic Choice Set Multinomial Logit (PCMNL) model was proposed and this generalised the standard MNL model used in previous airport access studies. Flight frequency turned out to be the most important factor.

Hess and Polak[5] considered the application of the Mixed Multinomial Logit (MMNL) structure to the analysis of airport choice in the San Francisco Bay area. The motivation was to allow for random distribution of tastes across air-passengers. Hess and Polak[5] is able to identify significant sampling bias in the air-passenger data set, where the passengers interviewed at the 3 main airports (San Francisco International Airport, San Jose International Airport and Oakland International Airport) are not representative of the actual real world traffic at these airports. The Weighted Exogenous Sampling Maximum Likelihood (MESML) approach was used to correct the biased sampling methodology where each observation was assigned a chosen alternative compared to its market share in the sample used in the analysis. Air-travel level-of-service variables investigated were airfares and frequency of flights on the different routes by the different airlines. The MMNL model used was that similarly applied by McFadden and Train (2000) as reported by Hess and Polak[5], but within the framework of passenger sensitivity difference to such factors such as fares and frequencies. To address the issue of diminishing marginal returns in utility, the use of a non-linear specification was adopted for only flight frequency after several attempts to apply it to the coefficients for fare and access time without any significant gains in model fit. It was found that access-cost had no significant impact in any of the models and so it was not possible to give an estimate of the value of access-time savings.

Bondzio[11] is able to jointly explain air passengers' choice of access mode and airport in terms of access-cost, access-time and service frequency for airports in south Germany. In the case of business travellers, the best performing models were obtained when airport choice is nested within access mode. Business travellers are found to value access-time more than leisure travellers.

Tam and Tam[14] recently performed a statistical analysis of airport access mode choice for the Hong Kong International Airport (HKIA) using a market share approach. Gap Analysis (GA) and Structural Equation Modelling (SEM) were applied and it was concluded that gender, age, educational level, flight length and travel cost negatively impact on the use of public transport for airport ground access.

This work was carried out in order to gain additional insight into the mode choice behaviour of air passengers using a disaggregate modelling approach. In doing so, certain new variables such as “luggage-count” and “access group size” are investigated in order to give a better behavioural interpretation for passengers’ mode choices.

THE CASE STUDY

The study airport is Newcastle International Airport (NCL) located in the Tyne and Wear district of England. In terms of passenger operations it is the largest in the northeast of England and the tenth largest in the entire UK[7]. In 2006, the number of passengers that travelled through the airport was 5.43 million (an increase of 5% over the 2005 figure). It is currently one of the fastest growing airports in the UK, growing steadily at a rate of 4-5% over the past 7 years[12]. Passenger ground access has been increasing accordingly and this makes NCL a suitable case study for a study of airport surface-mode choice. Passengers currently access the airport using six different travel modes: car (long-stay parking), car (short-stay parking), car-hire, taxi, metro and bus. In this study, the choice of any one of the identified modes is considered independent of any other travel choice confronting the decision maker (flight, airport or even destination). Given that there are more than two alternatives, a Multinomial Logit (MNL) structure is adopted under the common assumption of IIA (Independence of Irrelevant Alternatives).

THE REVEALED PREFERENCE (RP) QUESTIONNAIRE

The main philosophy behind the design of the Revealed Preference (RP) questionnaire was a desire to minimise agitation and frustration to respondents (air-passengers) as much as possible within pragmatic limits. The survey considered only residents of the Newcastle area (outbound air-traffic). Minimal questions were used to solicit the desired information. The questionnaire was broken down into three sections**:**

- Passenger's journey to the airport;
- Passenger's socio economic characteristics; and
- Characteristics of passenger's air trip

Travel Time (TT) and Travel Cost (TC) were identified as the best variables that can explain passengers' surface transport mode choices to the airport. In this study, the consideration has been placed on five main surface transport options: car-dropped off (CDRP), car-long stay parking (CLSP), metro (METRO), taxi (TAXI) and bus (BUS).

Socio-economic characteristics of the air-passenger, believed to influence mode choice to the case study airport, were also solicited and included: Possession of Drivers Licence (DRVL), Personal Gross Annual Income Group (INC), Household Car Ownership (HHC), Sex (SEX), Age (AGE), Size of Access Group (GRP), and Luggage Count (LUGG).

Characteristics of the air passenger's trip are expressed in terms of **:**(1) Purpose of Journey (PURP) i.e. business or leisure and (2) Type of Flight (FLT) i.e. domestic (final destination within the UK) or international (final destination outside the UK). This enabled the adoption of a market segmentation approach in the modelling of passengers' preferred access-mode to the airport. It was initially intended to collect a large and representative sample so that estimates do not significantly differ from the true or correct values. Practical concerns relating to resource and time were considered and a reasonable balance was achieved between accuracy and cost.

Enough time was allowed for data collection. This allowed the survey to be conducted several times with a more targeted approach. The survey was administered randomly to respondents as a paper-based face-to-face interview in order to minimise the number of incomplete responses. A pilot survey was carried out on 30 respondents in June 2006. For the main survey, respondents who had used NCL for their air travel within three months prior to the date of the survey were selected to ensure that their responses were accurate and acceptable for the analysis. The main survey was conducted in July 2006 at three different public spaces in the Tyne and Wear district (northeast of England):

- British Telecom (BT) Call Centre (318 questionnaires)
- Works and Pensions Department (200 questionnaires)
- The Metro Centre shopping mall in Gateshead (106 questionnaires)

PRELIMINARY DATA ANALYSIS

Data cleaning was confined to removal of questionnaires which contained illogical responses e.g. incorrect postcodes. In all, six of such questionnaires were identified and removed. The total number of valid responses analysed were therefore 618. Before developing the discrete choice models, the valid data was examined in order to gain an understanding of its composition over the various market segments. FIGURE 3 depicts the composition of the RP data obtained.

ESTIMATION OF TRAVEL COST

During data preparation it was discovered that the number of respondents who had chosen to access the airport by the car-hire mode could not permit any meaningful statistical analysis and therefore were left out of the analysis. The remaining five modes produced sufficient outcomes (numeric responses) and these were the alternatives that were eventually modelled. For users of public transport, travel cost was simply taken as the fare (out-of-pocket expense). In the case of passengers who accessed the airport via private car, access-cost was taken as the sum of fuel costs and any incurred parking expenses.

Estimation of Parking Cost

The cost of parking was derived for passengers who chose either of the two car alternatives; car (dropped-off) and car (long stay parking). This was based on how long an accompanied driver stayed at the airport or how long the passenger was away. Passengers were asked to state the duration of their travel or the time spent with them by an accompanied driver. Standard parking tariffs at NCL were obtained for this purpose. Such information was used to estimate parking charges incurred as a result of using the airport's short-stay or long-stay parking facility.

Estimation of Fuel Cost

Since fuel consumption is a function of distance, it was found necessary to first estimate the distance travelled by passengers accessing the airport via car (dropped off) or car(long stay parking). The origin postcodes of passengers were solicited in the RP survey. AUTOROUTE (an internet-based routing program on Google Maps) was then applied to obtain the distance (in miles) between a passenger's origin address and the fixed destination address of the airport. An average value of 10.92 pence per mile was derived for fuel consumption based on standard data published by the AA Motoring Trust for 2005[13]. This study recognises that the application of an average value for fuel consumption across individual decision makers is an aggregate technique. Extra questions in the questionnaire could have been asked to solicit the kind of information needed to ascertain fuel consumption for the individual decision maker. It was however thought that this would make the questionnaire more complex and ultimately compromise on the quality of the responses. The result of aggregating fuel cost is mitigated in this study by obtaining a varied data set. Thus, fuel cost is estimated using equation 1.

$$\text{Fuel Cost} = 10.92\ (\text{pence/mile})*\text{Distance (miles)} \quad (1)$$

Fuel and parking costs were respectively spread over the size of the access-group.

ESTIMATION OF TRAVEL TIME

Access-time was estimated using AUTOROUTE (on Google maps) for passengers who used either car (short-stay parking), car (long-stay parking) or taxi. Passengers who used either bus or metro were asked to explicitly state the time they perceived it took them to get to the airport. This included any walk and wait time in addition to in-vehicle time.

MODELLING AIR PASSENGER MODE CHOICE

The basic objective of the logit model is to estimate a function that determines outcome probabilities based on utility theory. Based on the descriptive analysis of the revealed preference dataset, alternative formulations of the mode choice models were tested. The main hypothesis used in this study is that passengers' choice of mode can be explained using the Random Utility Theory (RUT). Within this context the most widely applied modelling formulation used in discrete choice analysis, namely the logit model, was used.

Model Formulations

The utility associated with choosing any of the travel alternatives (U) is described in terms of observed variables (V) and unobserved factors in the form of an error term (ε). Using notations proposed by Ben-Akiva and Lerman[9], utility can be expressed as follows:

$$U_{in} = V_{in} + \varepsilon_{in} \quad (2)$$

Where,

U_{in}: the utility of alternative i for individual n.

V_{in}: the systematic (deterministic) component of utility of alternative i for individual n.

ε_{in} : the random (disturbance or error) component of utility of alternative i for individual n.

The individual is always assumed to choose an alternative with the highest utility. However, the utilities are not known to the analyst with certainty. The common practice of treating this uncertainty is by considering them as random variables.

$$P_{in} = P(U_{in} \geq U_{jn}, \ \ \forall j \in C_n, \ j \neq i) = P(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}, \ \ \forall j \in C_n, \ j \neq i) \quad (3)$$

Where,

j**:** any other alternative in C_n except i.

P_{in}: the probability that the individual n chooses alternative i.

C_n: the choice set of the individual n.

Under the assumption that ε_n (= ε_{jn}-ε_{in}) is logistically distributed, the probability that individual n chooses alternative i (P_{in}) is proposed by Ben-Akiva and Lerman (9) as:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j=1}^{n} e^{Vjn}} \qquad , \mathrm{e} = 2.718 \quad (4)$$

Development of the Mode Choice Model

Transport modes that are modeled in this study are; car-dropped off (CDRP), car-long stay parking (CLSP), metro (METRO), taxi (TAXI) and bus (BUS). The car (dropped-off) alternative refers to the case where a passenger's accompanied driver decides to use the airport's short-stay parking facility or the case where the driver simply drops the passenger off by the curbside and leaves without having to pay for parking. In specifying the functional form of utility, it was decided to use a linear-in-the-parameter specification after several attempts were made to specify some of the variables as log-variables (to allow for diminishing marginal utility) without any significant gain in model performance. Utility functions formulated for the different travel alternatives are given in appendix 1 (equations 7 through 11).

Model Estimation

The estimation of discrete choice models involves a search for the beta-values (parameters). The technique used is the Maximum Likelihood (ML) estimation procedure proposed by Ben-Akiva and Lerman[9].For any of the given alternatives, a search is done for the set of coefficients that maximises the chance of choosing that access mode instead of the others. Hence, the ML estimates are the best (least variance) linear unbiased estimators of the underlying population. The software programme Statistical Package Social Sciences (SPSS) *v 14* was used for estimation .Beta-values for the bus alternative are set to zero. Bus is therefore taken as the reference access mode to which outcome coefficients and probabilities are compared. Due to excessive correlation between travel time (TT) and travel cost (TC), model estimation was not possible with the inclusion of both variables. Based on model performance, TT was unanimously a more sensitive variable then TC. Therefore access-cost did not enter into any of the models.

Statistical Evaluation

Model performance was first of all assessed by considering the magnitude of the Rho-square (ρ^2) statistic, which indicates the extent to which a model fits the used data. Rho-square values > = 0.15 typically represent well fitted models. Secondly, models were evaluated based on the statistical significance of estimated parameters.This gives an indication as to whether the estimated coefficients are significantly different from the base value of zero which refers to the bus travel mode in this study.

MODEL RESULTS AND DISCUSSION

Mode Choice of Air Passengers - Basic Model

TABLE 1 gives the results for the basic model. An attempt is made here to explain mode choice in terms of only access time (TT). Inclusion of LUGG, HHC and GRP as dummy variables improves the model, captures the choice behaviour of passengers in general and produces a model with a satisfactory ρ^2 value of 0.18. All coefficients in the model are found to be significant at the 5% level.

The basic model reasonably demonstrates the mode choice behaviour of air passengers in terms of access or travel time. The mode constant is positive for all modes suggesting passengers' preference for these alternatives over bus. This is an expected outcome because passengers generally consider bus to be an inferior mode with greater waiting times and inconsistent schedules. In this study, "bus" does not include long distance coach services. In the case of car (long-stay parking), however, this was not a significant claim and this is attributable to the fact that high parking costs associated with car (long-stay parking) is well perceived and makes it not so popular against bus. In the basic model, all the modes are found to be preferred to bus for shorter access times although this could not be significantly stated for car (long-stay parking). Bus is not competitive in terms of cost over short distances in the study zone. Passengers are therefore drawn to the other modes in such cases, given their other advantages. In the basic model, TT, HHC and GRP produce alternating opposite effects on passengers' choices. If the number of cars in a passenger's household increases and there are less people in the access group then the passenger will prefer all modes to bus for shorter access times. All modes except metro are preferred over bus as luggage increases. The disparity luggage causes in the case of metro is explained as follows:

- Buses often offer safe luggage compartments (internally or externally) that relieve the passenger of the burden of having to watch over personal possessions while on the bus.
- Greater disutility is associated with having to carry luggage up and down escalators and ramps commonly found at many of the Tyne and Wear metro stations.

Models for the different market segments

Models were also estimated in this study for different markets of air passengers. The set of variables included in these sub-models depended on the value of the goodness-of-fit statistic and the significance of beta-values for different combination trials. Passengers were segmented according to**:**

- Purpose of journey (leisure or business)
- Type of flight (domestic or international) and;
- Gross personal income (in pounds sterling)

1. Leisure and Business Passengers

For Leisure passengers, mode choice behaviour was best explained in terms of TT, HHC and LUGG.The mode choice behaviour of business passengers was however best explained in terms of only TT and HHC.The model developed for business passengers had a better fit than that for leisure passengers (ρ^2 of 0.26 compared to 0.17) and overall was the best fitted model in this study. TABLE 2 summarizes estimation results for both leisure and business air passengers. By comparing model estimates shown in TABLE 2, business passengers, overall, are found in this study to be more sensitive to access time than leisure passengers. For the specific case of car (dropped-off) and car (long-stay parking), however, both passenger groups value access-time almost the same. Household Car Ownership (HHC) is observed to be a more important determinant of mode choice (all the modes except metro) for business passengers than for leisure passengers. The magnitudes of Alternative Specific Constants (ASCs) reveal that both passenger groups naturally prefer all access modes to bus except with the car-long stay parking (CLSP) alternative, where both business and leisure passengers have an inclination toward bus.

2. Domestic and International Passengers

The variables that best explain the choice behaviour of domestic passengers are TT, LUGG and GRP. For international passengers, the best fitted model is obtained by including all variables (TT, LUGG, HHC and GRP) .International passengers (ρ^2 of 0.19) produce a better fitted model than domestic passengers (ρ^2 of 0.14) with all coefficients being significant at the 5% level. TABLE 3 compares estimation results for domestic and international passengers. For domestic passengers, CDRP and CLSP are converted into a single car mode to ensure sufficient statistical responses. Domestic passengers value access-time more than international passengers in this study. This is attributed to the fact that domestic passengers have tighter check-in times whereas international passengers are normally required to arrive at the airport 2-3 hours before their flight. The LUGG variable, while producing significant coefficients for the individual groups, did not offer any meaningful pattern in mode choice when the two groups are compared. Size of Access Group (GRP) was unanimously a more important variable for international passengers than for domestic passengers. Domestic passengers are observed to prefer all modes to bus than their international counterparts.

3. Income Group 1 and Income Group 2 Passengers

Two income groups are formulated and modelled based on the gross personal earnings of air passengers**:** (1) Income Group 1 (less than £20,000 per annum) and (2) Income Group 2 (£20,000 or more per annum). For Income Group 1, TT, LUGG, HHC and GRP were all included in order to achieve the highest fit ($\rho^2 = 0.20$).For Income Group 2, the combined effect of TT, HHC and GRP yielded the best fitted model ($\rho^2 = 0.21$). For the two formulated income groups, all the coefficients are greater than zero at the 10% level of significance. TABLE 4 gives the results of estimated coefficients for Income Groups 1 and 2. Income group 2 is unanimously more sensitive to access time than Income group 1 for all access modes. This was an expected outcome. Income group 2 is also more sensitive to HHC than Income group 1 for all modes except metro. This was also expected because higher earning passengers value time more than relatively lower income earning passengers and will derive greater satisfaction from the use of a faster car alternative. Income group 1 is more sensitive to the GRP variable than Income group 2 for all modes except taxi. No trend could be seen in Alternative Specific Constant (ASC) values for all modes (when comparing the two income groups); however passengers who earn £20,000 or more are highly attracted to taxi naturally.

INTERPRETATION OF COEFFICIENTS

A quantitative interpretation of the estimated parameters (β-values) is given in this study using the concept of odd ratios which is expressed mathematically by equation 5[8, 9]:

$$\left(\frac{P_i}{1-P_i}\right)_{NEW} = \left(\frac{P_i}{1-P_i}\right) \cdot EXP^{\beta_i} \tag{5}$$

Thus for every one unit increase in the independent variable X_i (travel time, size of access group, household car ownership or luggage count), the odds ($P_i/1-P_i$) increases by a factor EXP^{β}. Applying this to the case of the base model (TABLE 1), some findings obtained are:

- The addition of an extra automobile in a household has the effect of increasing the odds of using car (long stay parking) rather than bus by a factor of 6 (approximately)
- For every 10-minute increase in travel time by car, the odds that a passenger will select car (long stay) rather than bus is reduced by a factor of 0.4 (approximately)
- The odds of using car (dropped-off) rather than bus reduces by 0.632 (greater than half) if the size of the access group increases by one member.

This approach can also be extended similarly to test the sensitivity of the independent variables on mode choice for the various market segments modelled in this study.

Policy Implications

Marginal Rate of Substitution (MRS) values were calculated for pairs of variables in the developed utility functions for each mode. This provided the trade-offs that passengers are making between the attributes. For MNL models, Marginal Rate of Substitution values are obtained by simply dividing the coefficients of the two variables of interest[8, 9].

$$MRS(i)_{ba} = \frac{\beta_{ai}}{\beta_{bi}} \qquad (6)$$

Some results of this analysis are:

~For every additional 18 minutes that is encountered in accessing the airport, respondents who choose metro are observed to reduce their luggage by one piece.

~For every 11 minutes that is encountered in accessing the airport, respondents who choose car (drop-off) are observed to reduce the number of people accompanying them to the airport by one person.

~ For every 16 minutes that is encountered in accessing the airport, respondents who choose car (long-stay parking) are observed to reduce the number of people accompanying them to the airport by one person.

~For every 12 minutes that is encountered in accessing the airport, respondents who choose taxi are observed to reduce the number of people accompanying them to the airport by one person.

CONCLUSIONS

While this is a case study, and hence a snapshot of the choices at one particular airport for locally based travellers, the results of empirical analysis show that the estimated models can be used as an effective tool or guide to represent the behaviour of air passengers as they embark on the independent decision of choosing an airport ground access mode. Revealed preference data on passengers' choices provides the most reliable measure of actual behaviour and in this instance was sufficient to meet the main objective of this study. The results also indicate that in the specific case of airport ground access, mode choice is heavily reliant, not only on traditional level of service variables such as access-time and access-cost but, on other factors such as the number of cars in a passenger's household (HHC), size of the access group (GRP) and amount of luggage being carried to the airport (LUGG). These variables significantly explain choice behaviour for passengers in general and for individual market segments. Bus is taken as the reference travel alternative in this study. While this allows for estimation of the unknown parameters, it also has the benefit of comparing choice behaviour of other access modes to that of a more cost-effective and widely favoured option.

Estimated coefficients are also put into perspective by giving a quantitative interpretation to them so that decision makers are able to better understand the actual impact these variables have on passenger mode choice behaviour. Subsequently, the decision maker will have a better understanding of the trade-offs made by passengers between the different attributes considered in this study.

REFERENCES

1. Upham P. Thomas C. Gillingwater D. and Raper D. Environmental capacity and airport operations: current issues and future prospects. *Journal of Air Transport Management*, 2003, **9**, No.3, 145-151.
2. Skinner R.E. Airport choice: an empirical study. *Transportation Engineering Journal*, 1976, **102**, No. 4, 871-882.
3. Pels E. Nijkamp P. and Rietveld P.Access to and competition between airports: a case study of the San Francisco bay area, *Transportation Research Part A: Policy and Practice*, 2003, **37**, No.1, 71-83.
4. Bhat C.R. and Basar G. A parameterised consideration set model for airport choice: an application to the San Francisco bay area. *Transportation Research B*, 2004, **38** 889-904.
5. Hess S. and Polak J.W. Mixed logit modelling of airport choice in multi-airport regions. *Journal of Air Transport Management*, 2005, **11**, No.2, 59-68.
6. Hess S. and Polak J.W. Development and application of a model for airport choice in multi-airport regions.*CTS Working Paper, Centre for Transport Studies, Imperial College, London,* 2004.
7. CAA (2003), UK Airport Statistics. See http://www.caa.co.uk. Accessed 05/06/2006.
8. Washington S.P. Karlaftis M.G. and Mannering F.L. *Statistical and Econometric Methods for Transportation Data Analysis*, 2nd edition, Chapman and Hall, Boca Raton, Florida, 2003.

9. Ben-Akiva M. and Lerman S.R.*Discrete Choice Analysis*, MIT Press, Massachusetts 1985.

10. Cunningham L.F. and Gerlach J.H. Transportation agencies' experiences with decision support systems for airport ground access planning, *Transportation* ***25***,37-53 Kluwer Academic Publishers,1998.

11. Bondzio L. Disaggregate planning models for airport access. PhD thesis, Ruhr University, Bochum, 1996.

12. Wikipedia, The Free Encyclopedia, Newcastle Airport. See http://en.wikipedia.org/wiki/Newcastle_Airport#Statistics. Accessed 05/06/2006.

13. AA Motoring Trust. See http://www.theaa.com. Accessed 05/06/2006.

14. Tam M.L. and Tam M.L. Analysis of airport access mode choice: a case study in Hong Kong, *Journal of Eastern Asia Society for Transportation Studies*, 2005, **16,** 708-723.

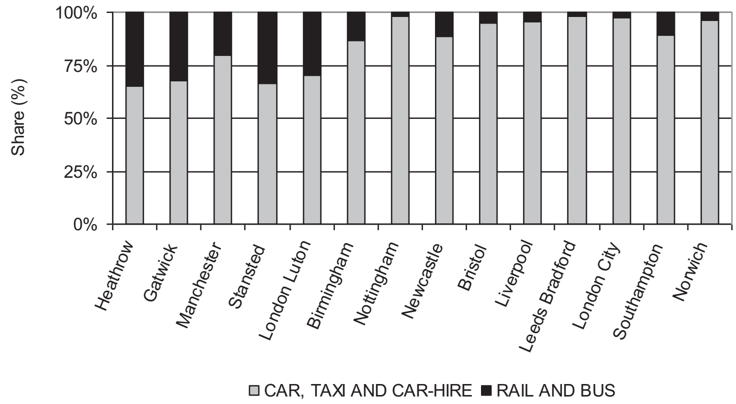
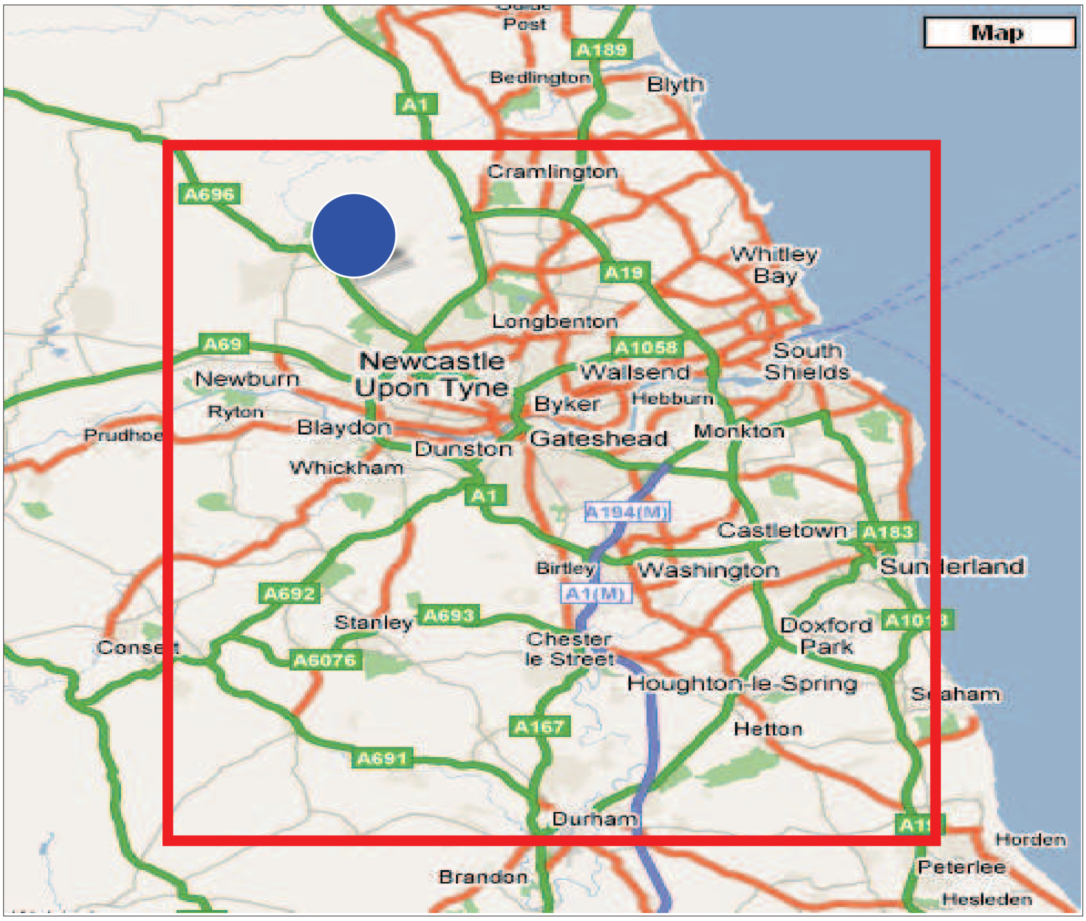


FIGURE 1 Modal split for air-passengers accessing UK airports.



Notes:

The “red outline” represents the geographical reach of respondents;
The “blue dot” represents the location of NCL;

Local roads Arterial roads

FIGURE 2 Core study area captured in the RP survey *(source of map: Google)*

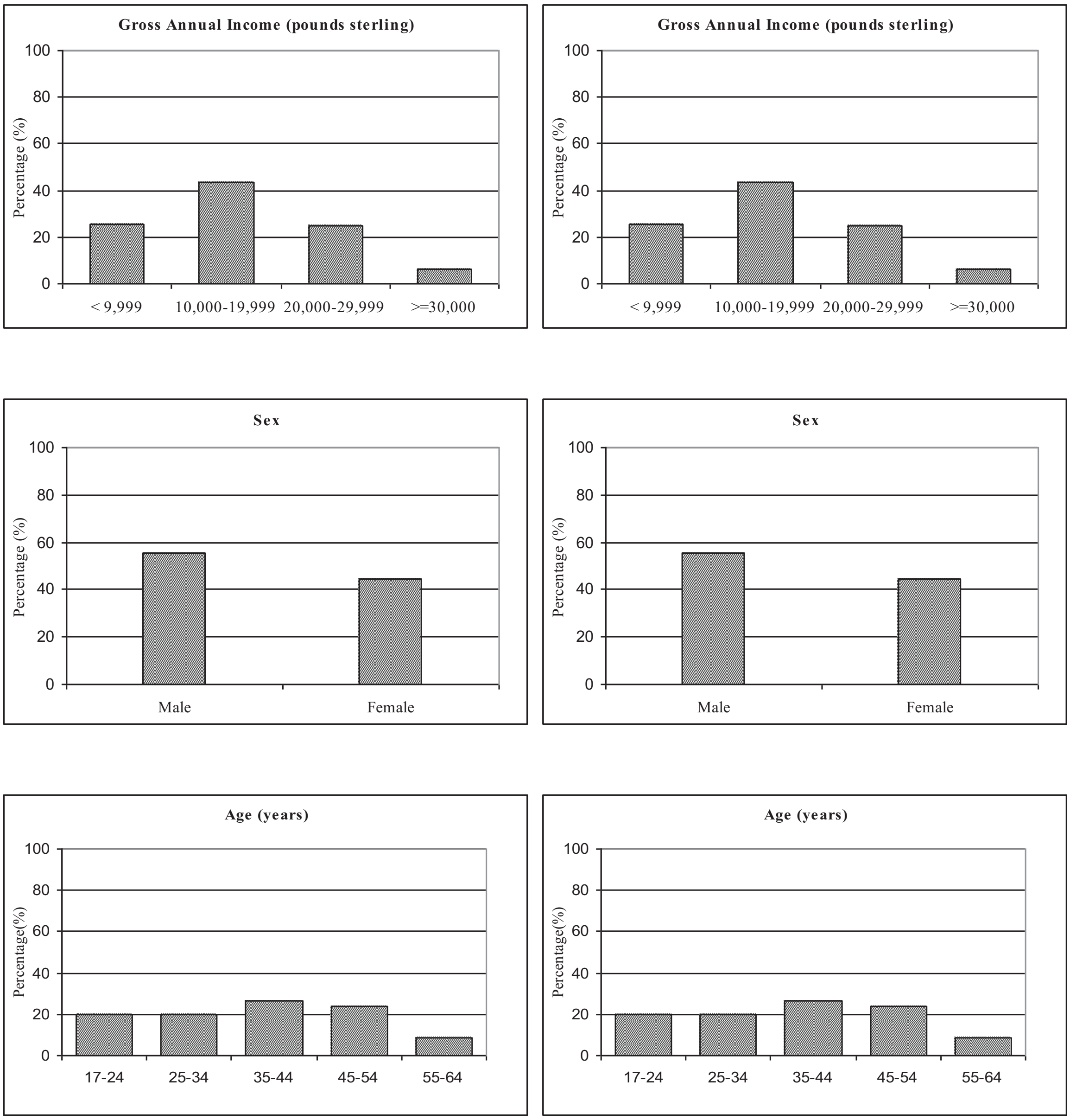


FIGURE 3 Database statistics

TABLE 1 Estimation Results-the Basic RP Model.

Variable	Coefficient	t-statistic
Alternative Specific Constants		
Bus*(BUS)*	0	**--**
Car-dropped off *(CDRP)*	**1.80**	2.94
Car-long stay parking *(CLSP)*	**-1.83**	2.83
Taxi *(TAXI)*	**1.40**	2.67
Metro *(METRO)*	**4.01**	6.90
Level of Service Variables		
Travel Time (TT)		
Car-dropped off *(CDRP)*	**-0.09**	-6.13
Car-long stay parking *(CLSP)*	**-0.04**	-2.86
Taxi *(TAXI)*	**-0.06**	-5.33
Metro *(METRO)*	**-0.05**	-4.00
Alternative Specific Dummies		
Luggage count (LUGG)		
Car-dropped off *(CDRP)*	0.58	2.49
Car-long stay parking *(CLSP)*	**1.03**	4.33
Taxi *(TAXI)*	**1.01**	4.19
Metro *(METRO)*	**-0.93**	-3.91
Household Car Ownership (HHC)		
Car-dropped off *(CDRP)*	**1.58**	6.80
Car-long stay parking *(CLSP)*	**1.73**	6.95
Taxi *(TAXI)*	**0.90**	4.15
Metro *(METRO)*	0.55	2.41
Size of Access Group (GRP)		
Car-dropped off *(CDRP)*	**-1.00**	-5.06
Car-long stay parking *(CLSP)*	**-0.64**	-3.11
Taxi *(TAXI)*	**-0.79**	-4.53
Metro *(METRO)*	**-0.52**	-2.82
Summary Statistics		
Number of RP Observations	618	
L(**0**)	-873.062	
L(**β**)	-703.591	
ρ^2	0.181	

Notes:

0 in "Coefficient." column indicates that the constant term set to zero.
-- in columns "Coef." and "*t*-stat." indicates that those variables are not considered in the model
Bold figures are significant at 95%

TABLE 2 Estimation Results (Leisure and Business Passengers).

Variable	Purpose of Travel			
	Leisure Passengers		*Business Passengers*	
	Coefficient	t-statistic	Coefficient	t-statistic
Alternative Specific Constants				
Bus *(BUS)*	0	--	0	--
Car-dropped off *(CDRP)*	**1.82**	2.67	1.47	1.23
Car-long stay parking *(CLSP)*	**-1.91**	-2.41	**-2.63**	-1.78
Taxi *(TAXI)*	**0.91**	1.56	**3.53**	3.40
Metro *(METRO)*	**4.05**	6.18	**2.90**	2.38
Level of Service Variables				
Travel Time (TT)				
Car-dropped off *(CDRP)*	**-0.08**	-4.41	**-0.11**	-3.24
Car-long stay parking *(CLSP)*	**-0.03**	-1.88	**-0.03**	-0.97
Taxi *(TAXI)*	**-0.04**	-2.92	**-0.13**	-4.10
Metro *(METRO)*	**-0.03**	-2.36	**-0.09**	-2.486
Alternative Specific Dummies				
Luggage Count (LUGG)				
Car-dropped off *(CDRP)*	-0.12	-0.55	--	--
Car-long stay parking *(CLSP)*	**0.67**	2.88	--	--
Taxi *(TAXI)*	**0.50**	2.51	--	--
Metro *(METRO)*	**-1.48**	-5.80	--	--
Household Car Ownership (HHC)				
Car-dropped off *(CDRP)*	**1.29**	5.12	**2.05**	4.03
Car-long stay parking *(CLSP)*	**1.28**	4.68	**2.88**	5.07
Taxi *(TAXI)*	**0.58**	2.43	**1.35**	2.96
Metro *(METRO)*	**0.49**	1.96	**-1.40**	1.70
Summary Statistics				
Number of RP Observations	484		134	
L(**0**)	1247.28		345.01	
L(**B**)	1001.89		241.11	
ρ^2	0.17		0.26	

Notes:

0 in "Coefficient." column indicates that the constant term set to zero.
-- in the columns "Coef." and "*t*-stat." indicates that those variables are not considered in the model.
Bold figures are significant at 95%.

TABLE 3 Estimation Results (Domestic and International Passengers).

Variable		Type of Flight			
		Domestic Passengers		*International Passengers*	
		Coefficient	t-statistic	Coefficient	t-statistic
Alternative Specific Constants					
Bus *(BUS)*		0	--	0	--
Car-dropped off *(CDRP)*	CAR	**2.64**	2.54	**2.15**	2.77
Car-long stay parking *(CLSP)*				**-1.05**	-1.36
Taxi *(TAXI)*		**3.14**	2.75	**1.59**	2.49
Metro *(METRO)*		**5.34**	4.24	**3.90**	5.50
Level of Service Variables					
Travel Time (TT)					
Car-dropped off *(CDRP)*	CAR	**-0.08**	-3.46	**-0.08**	-4.16
Car-long stay parking *(CLSP)*				**-0.05**	-2.83
Taxi *(TAXI)*		**-0.12**	-4.21	**-0.06**	-3.67
Metro *(METRO)*		**-0.10**	-3.54	**-0.04**	-2.44
Alternative Specific Dummies					
Luggage Count (LUGG)					
Car-dropped off *(CDRP)*	CAR	**0.84**	2.01	0.21	0.75
Car-long stay parking *(CLSP)*				**1.08**	3.92
Taxi *(TAXI)*		0.83	1.88	**0.95**	4.01
Metro *(METRO)*		**-1.29**	-2.40	**-0.99**	-3.62
Household Car Ownership(HHC)					
Car-dropped off *(CDRP)*		--	--	**2.05**	6.10
Car-long stay parking *(CLSP)*		--	--	**2.17**	6.32
Taxi *(TAXI)*		--	--	**1.39**	4.39
Metro *(METRO)*		--	--	**1.29**	3.92
Size of Access Group (GRP)					
Car-dropped off *(CDRP)*	CAR	**-0.52**	-1.81	**-1.15**	-4.32
Car-long stay parking *(CLSP)*				**-1.01**	-3.76
Taxi *(TAXI)*		-0.54	-1.69	**-1.04**	-4.46
Metro *(METRO)*		-0.18	-0.55	**-0.84**	-3.41
Summary Statistics					
Number of RP Observations		170		448	
L**(0)**		472.22		1262.54	
L**(B)**		364.84		1011.70	
ρ^2		0.14		0.19	

Notes: car (dropped off) and car (long stay) are combined to produce a single "car" mode for domestic passengers
0 in "Coef." column indicates that the constant term set to zero
-- in the columns "Coef." and "*t*-stat." indicates that those variables are not considered in the model. Bold figures are significant at 95%.

TABLE 4 Estimation Results (Income Group 1 and Income Group 2).

Variable	Gross Annual Income (pounds sterling)			
	Income 1 (< 20,000)		*Income 2 (>= 20,000)*	
	Coefficient	t-statistic	Coefficient	t-statistic
Alternative Specific Constants				
Bus*(BUS)*	0	--	0	--
Car-dropped off *(CDRP)*	1.02	1.28	**3.86**	3.72
Car-long stay parking *(CLSP)*	**-2.79**	-3.21	0.44	0.40
Taxi *(TAXI)*	0.28	0.42	**5.07**	4.90
Metro *(METRO)*	**3.54**	5.06	**3.54**	3.31
Level of Service Variables				
Travel Time (TT)				
Car-dropped off *(CDRP)*	**-0.10**	-4.81	**-0.13**	-4.48
Car-long stay parking *(CLSP)*	**-0.04**	-2.32	**-0.07**	-2.64
Taxi *(TAXI)*	**-0.05**	-3.07	**-0.17**	-5.50
Metro *(METRO)*	**-0.04**	-2.60	**-0.08**	-2.89
Alternative Specific Dummies				
Luggage Count (LUGG)				
Car-dropped off *(CDRP)*	**1.05**	3.33	--	--
Car-long stay parking *(CLSP)*	**1.50**	4.47	--	--
Taxi *(TAXI)*	**1.41**	4.95	--	--
Metro *(METRO)*	**-0.72**	-2.48	--	--
Household Car Ownership(HHC)				
Car-dropped off *(CDP)*	**1.67**	5.57	**1.84**	4.21
Car-long stay parking *(CLS)*	**1.56**	4.79	**2.40**	5.14
Taxi *(TAXI)*	**0.87**	3.08	**1.52**	3.57
Metro *(METRO)*	**0.79**	2.76	-0.34	-0.69
Size of Access Group (GRP)				
Car-dropped off *(CDRP)*	**-0.99**	-3.86	**-0.91**	-3.35
Car-long stay parking *(CLSP)*	-0.45	-1.60	-0.43	-1.66
Taxi *(TAXI)*	**-0.73**	-3.27	**-0.57**	-2.26
Metro *(METRO)*	**-0.68**	-2.95	**-0.80**	-2.58
Summary Statistics				
Number of RP Observations	426		192	
L**(0)**	1193.37		541.14	
L**(B)**	944.42		414.79	
ρ^2	0.20		0.21	

Notes:

0 in “Coef.” column indicates that the constant term set to zero.
-- in the columns “Coef.” and “*t*-stat.” indicates that those variables are not considered in the model.
Bold figures are significant at 95%.